Grasping and Manipulation

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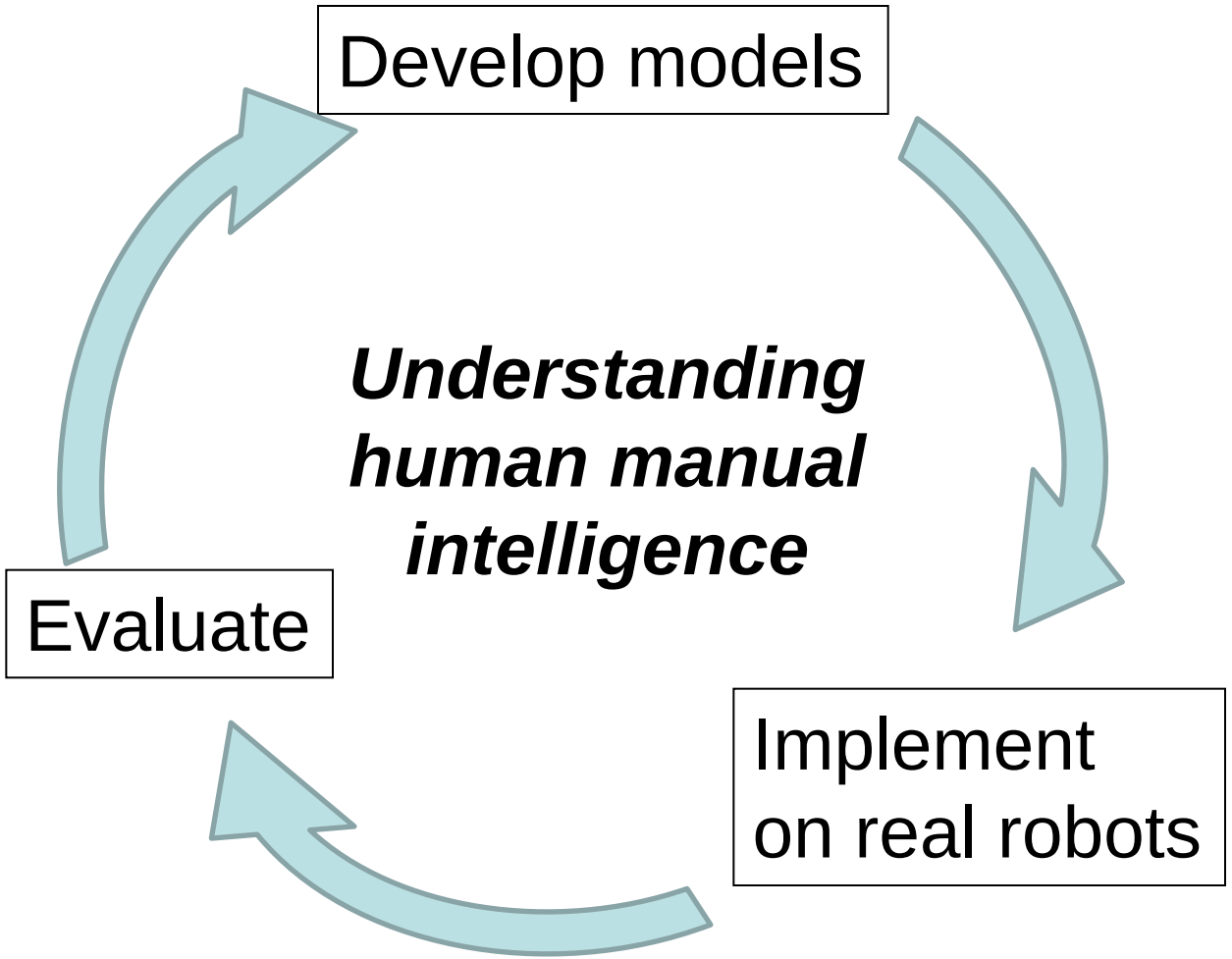
Outline

- Research Background
- Robotic Grasping Approaches
- Grasp Quality Criteria
- Modelling System Behaviour

Human Cognitive Capabilities



Research Objectives

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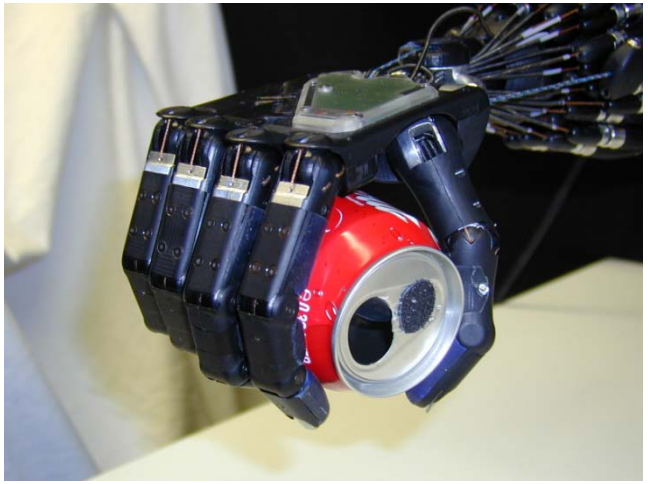
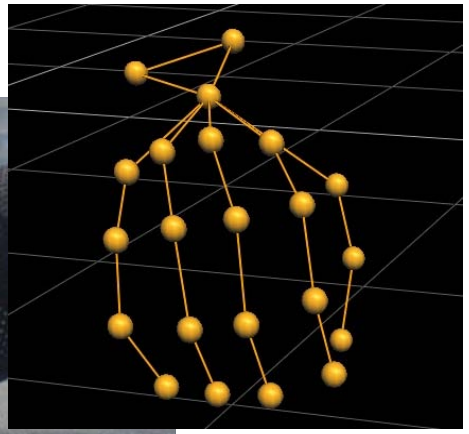
- autonomous grasping
- modelling complex manipulation actions
- Imitation learning
- Autonomous exploration





Multi-Modal Robot Instruction

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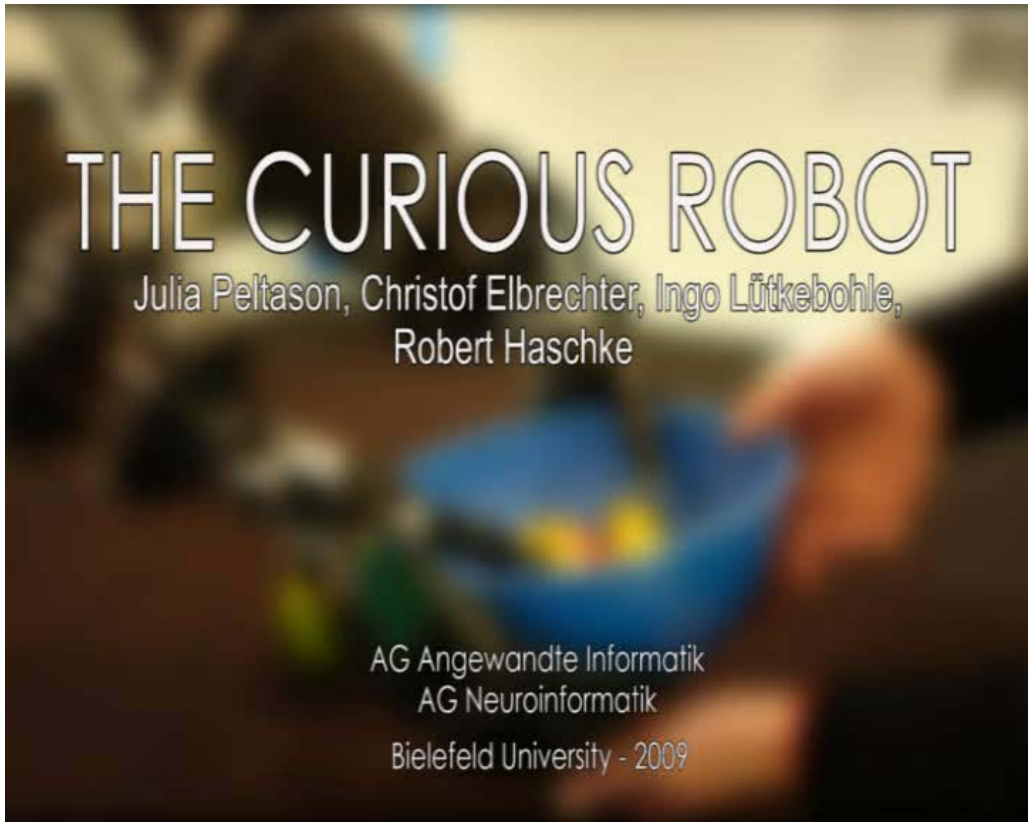
Study Interactive Learning from human

- multi-modal communication
- learning by imitation
- system architectures for integration



Modelling Grasping

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- Grasps are situation-specific
  - Shape, weight, friction properties
  - Goal-oriented
  - End-state comfort effect
  - Action history (hysteresis effects)
- Recurring basic grasp types

Cutkosky's Grasp Taxonomy

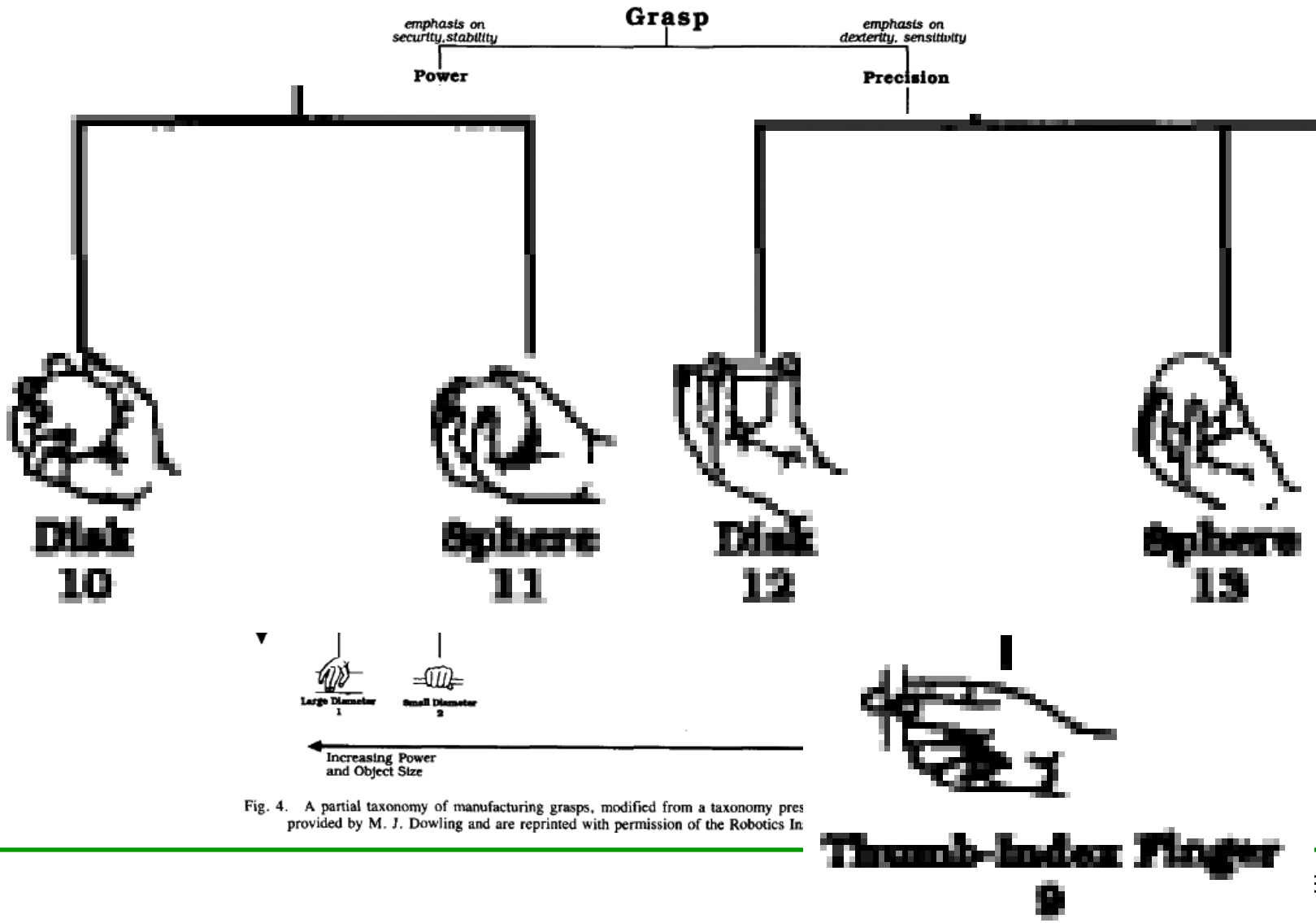

Fig. 4. A partial taxonomy of manufacturing grasps, modified from a taxonomy pres
provided by M. J. Dowling and are reprinted with permission of the Robotics In

Dextrous robot hands

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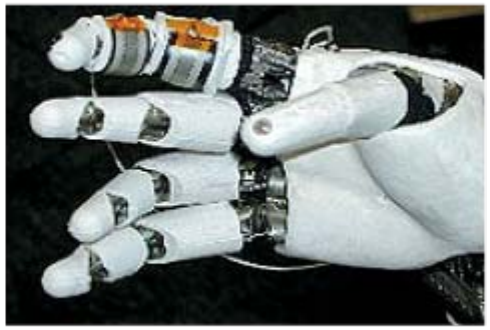

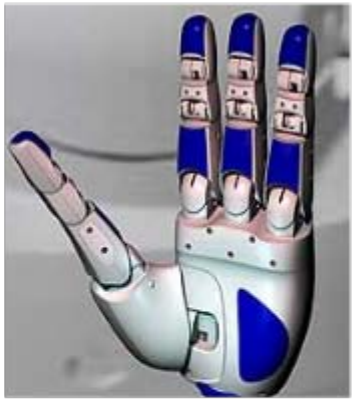

Grasping Approaches

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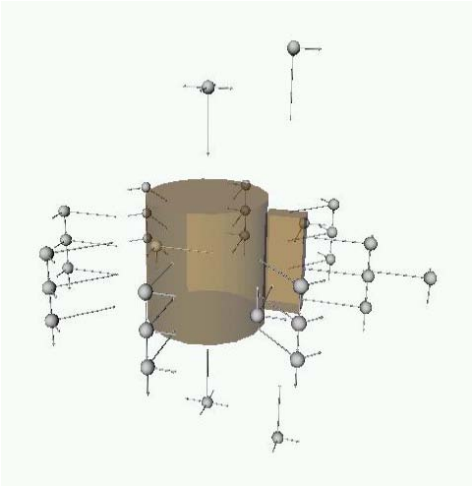
- model-based, analytical
  - optimal contact points, inverse kinematics
  - 2 optimization problems
- model-based, holistic
  - contact-based finger closing
  - simulation-based grasp generation and evaluation
  - forward application to real world
- model-free, holistic
  - tactile-based finger closing



Analytical Approach

- randomly choose contact points on object surface
- verify force-closure (expensive)
- first check two failure candidates of F_{ext}
  - bisector of the two contact normals with largest angle
  - average of all contact normals
- find feasable movement to reach contact points using resolved motion rate control
- candidate contact points may fail because
  - grasp is not force-closure
  - contact points cannot be reached

Grasping Strategy

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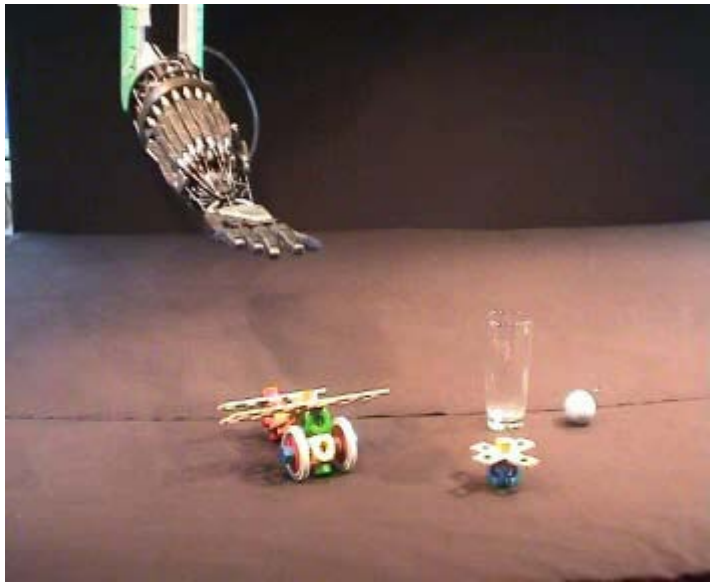
biologically plausible grasping concept

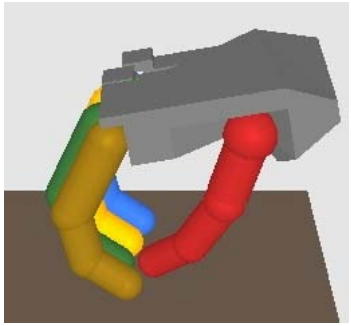
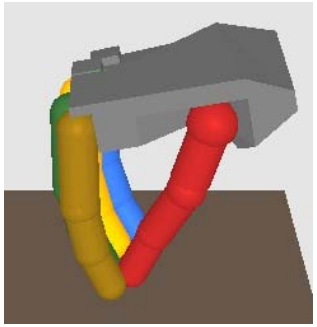
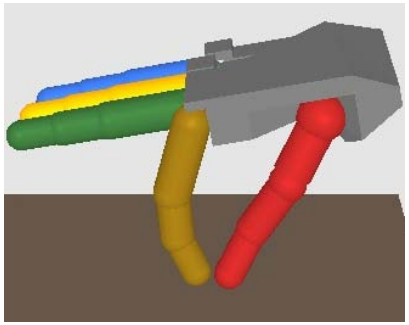
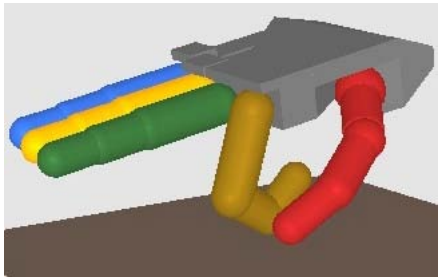
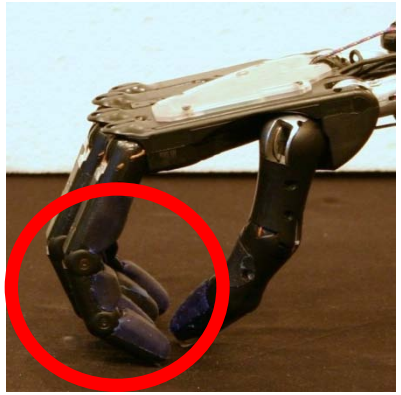
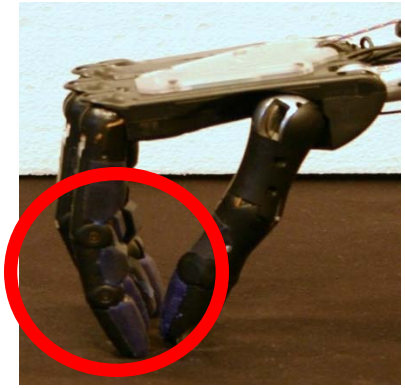
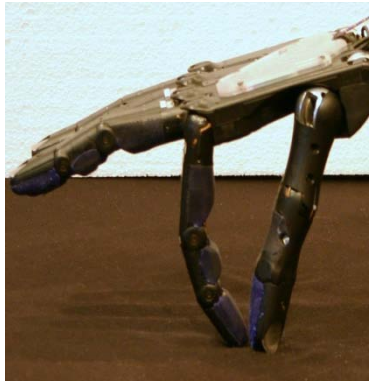
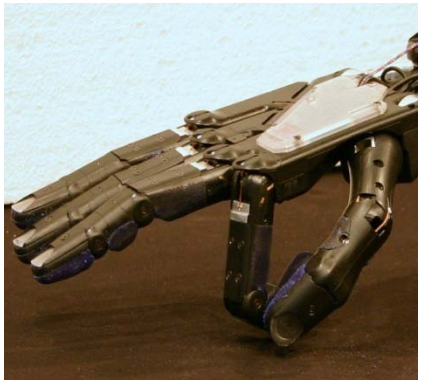
- inverse hand kinematics not needed
- approach movement
- rough pregrasp posture
- fine positioning
- contact-based closing



Grasp Adaptation

- several trials needed for good grasp
- iteratively adapt
  - pregrasp posture: synchronize contact
  - thumb opposition:
    evolutionary optimization (2 DOFs)

Grasp Optimization - Results

power grasp | precision grasp | pincer grasp | clamping grasp

Evaluation: 21 everyday objects

Grasp Analysis

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- grasp evaluation needed
- quality criteria:
  - *force closure*
    = passive resistence to external forces
  - *manipulability*
    = active application of forces
- too general concepts
- task-specific criteria needed

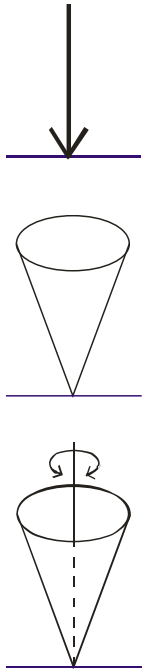
Grasp Description I

- contact points
- friction models
  - point contact w/o friction

    $0 < f_n$
  - Coulomb friction

    $|f_t| < \mu f_n$
  - soft finger contact

    $|f_t| < \mu f_n$ and $|\tau| < \gamma f_n$



Grasp Description II

- grasp matrix G
  transfers contact forces x
  into net object wrench F_O

$$F_O = G\,x$$

- wrench space W:
  set of all object wrenches F_O
  applicable through bounded contact forces

$$W = \left\{ G\,x \;\middle|\; x \in FC \text{ and } \|x\| \leq 1 \right\}$$

Wrench Space Example

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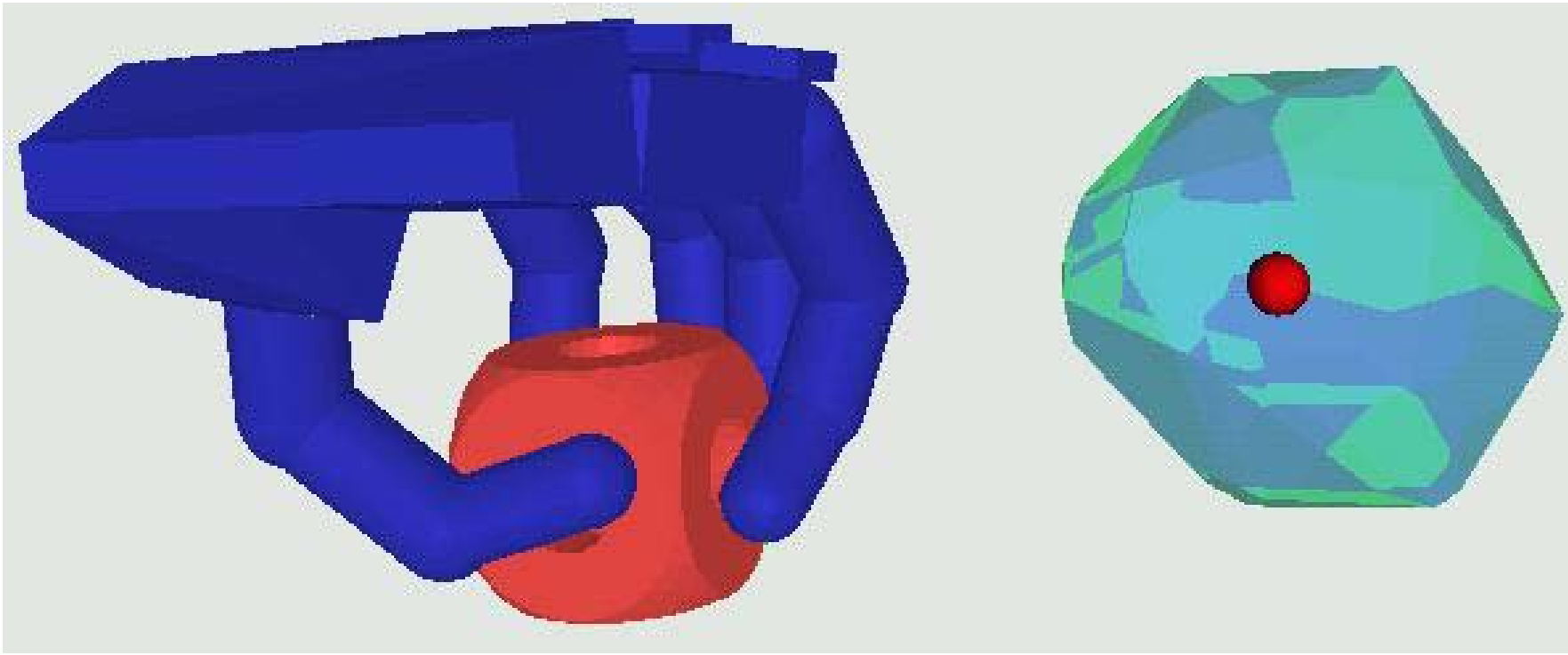
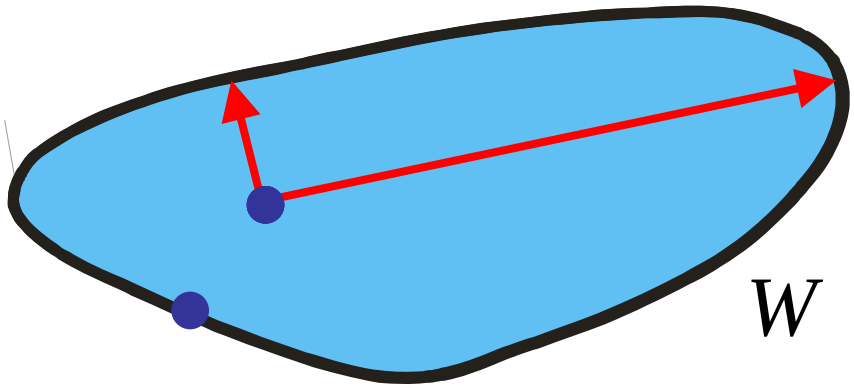


- simulated grasp
- many contacts
- large wrench space
- origin in center

Quality Measures using Wrench Space



- worst case disturbance
- unstable grasp
- specific task direction
- volume = average quality

Integrating Tactile Sensing

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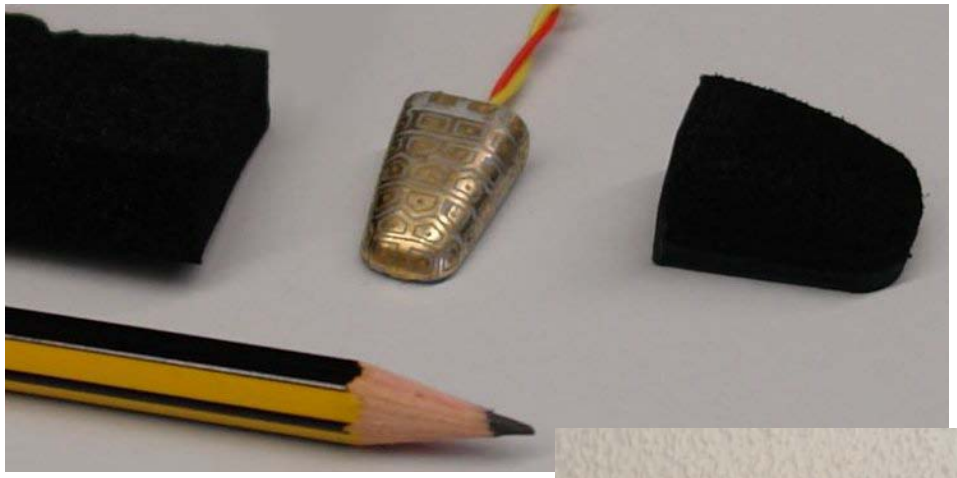

Tactile Fingertip

Tactile Glove

Tactile Object

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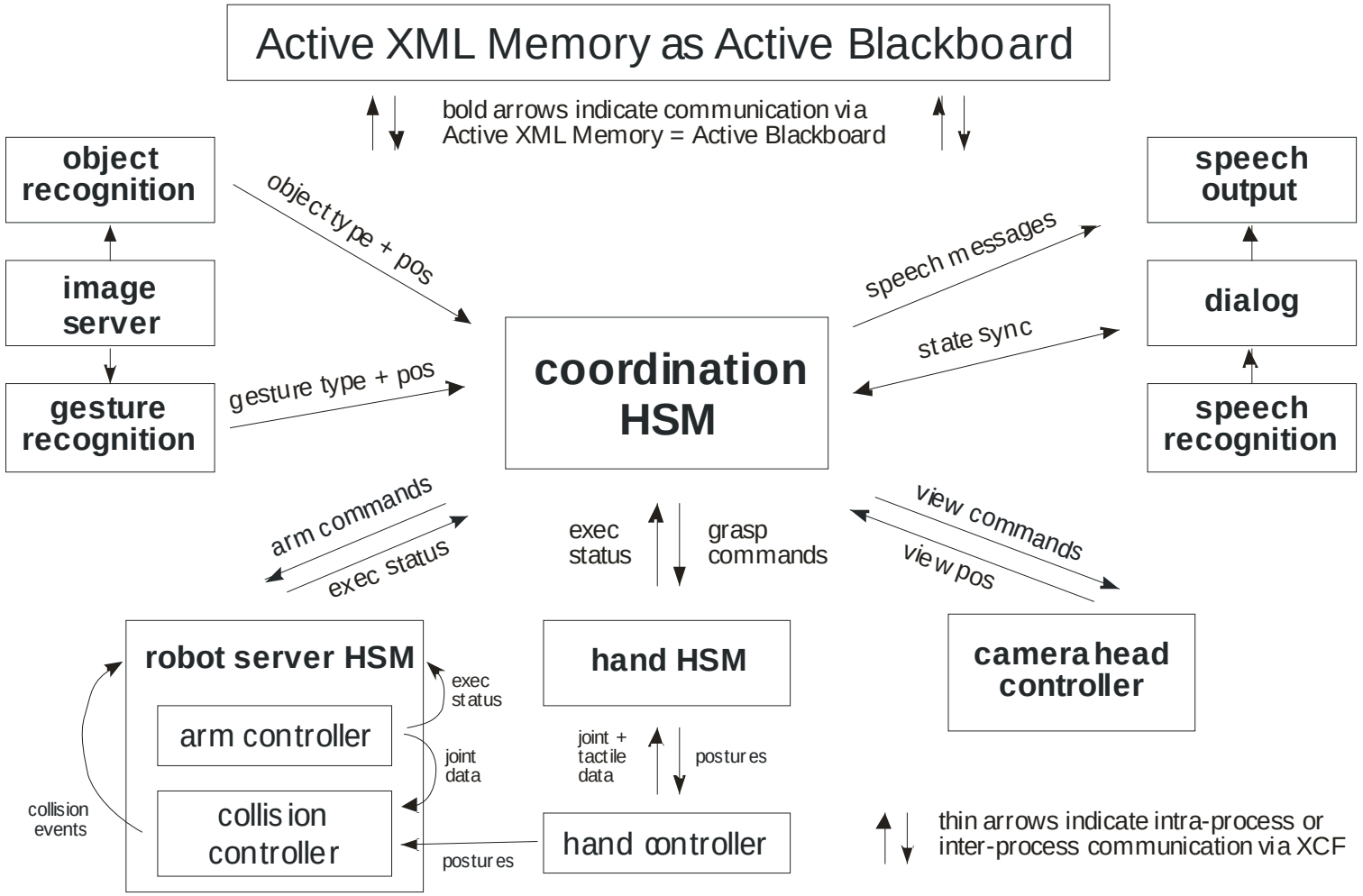
Distributed Architecture



Event-Based Communication

- asynchronous event communication
- decoupling of components
- content: XML messages
  - human readable
  - content-based subscriptions
  - abstracts from components

Organization of Behaviour

- events trigger state transitions
- state machine models behaviour
- transitions generate actions
- disadvantage:
  large state and event space
- parallel regions
  decouple orthogonal state spaces

Hierachical State Machines

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- Hierarchical Organization of States
  - unhandled events forwarded to parent state
  - common behaviour grouped in parent states
  - reduces state-action table